WASTE CHARACTERIZATION STUDY FOR MUNICIPAL SOLID WASTE DISPOSAL AT BERCHAM, IPOH

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CERTIFICATION OF APPROVAL

Waste Characterization Study for Municipal Solid Waste Disposal at Bercham, Ipoh

by

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Approved by,

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ZIANA SYAMIMI BINTI GHAZALI

ABSTRACT

A large quantity of solid wastes is generated in the city of Ipoh to be disposed off by landfilling method. Waste characterization study was conducted for the planning to reduce the waste, set up recycling programs, and conserve money and resources. This study was done to determine the composition of the solid waste in Bercham Landfill. A total of six samples were collected from three different places on two different days. Each sample was about 100 kg and divided into four parts. From that, one part was chosen randomly for second division. A quarter from the second division was finally characterized into paper, plastic, plastic container, metal & rubber, glass, food waste, fabric, leather, aluminum, and fiber. Two residential areas, one Chinese and another one Malay residential area were selected for the study. The results indicate that the highest percentage of waste component that generated on Wednesday and Friday is food waste. While fiber and glass is the major component generated by industrial area on Wednesday and Friday. Detail characteristics of the solid waste include the physical composition, moisture content, specific weight, ultimate analysis and energy content. The average moisture content for the waste sample from Jelapang residential area, Taman Meru residential area, and Puncak Jelapang industrial area is 35.29%, 42.50%, and 15.09% respectively. The average specific weight for waste sample from Jelapang residential area, Taman Meru residential area, and Puncak Jelapang industrial area is 103.229kg/m^3, 77.295kg/m^3 and 49.268kg/m^3 respectively. While the net energy content of the waste sample from Jelapang residential area, Taman Meru residential area, and Puncak Jelapang industrial area is 11 869 kJ/kg, 12 389 kJ/kg, and 17 026 kJ/kg respectively.

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CHAPTER 1
INTRODUCTION

1.1 Project Background

Solid Waste Characterization Study was conducted on fresh waste samples, which the wastes are going to be disposed off at Bercham Landfill. Bercham Landfill has been operated since 1986 after Buntong Landfill was closed. It is located at Batu 8, Jalan Bercham, Tanjung Rambutan which is 14 km from city center, 90 m from residential area, 15 m from main road, and 15 m from Choh's river. In general, it receives waste from 22 500 premise that scattered within 137 km^2 of area.

At the beginning, the Bercham Landfill was operated using Controlled Tipping method, but later it becomes open dumping type. There is a need for the city of Ipoh to have a proper waste disposal method. As the quantities of solid wastes are increasing in all cities and towns due to industrialization and urbanization, the concerns about the environmental compatibility of the present waste management method have been raised. Hence, an updated waste characterization is necessary to obtain detailed statistical information for use in developing effective solid waste management system.

In this study, the Solid Waste Characterization was conducted in three places/areas that contribute to waste's sources. This study was carried out between July 2009 and October 2009 on two different days which are Wednesday and Friday.

1.2 Problem Statement

Regarding the waste disposal management at the Bercham landfill, there are three things that Ipoh Municipality Council needs to give attention. These are:

1. No proper documentation on the solid waste characterization study.
2. The wastes are not well treated.
3. Leachate generation and methane gas emission are potentially polluting the environment in the surrounding area.

1.3 Objectives

Based on the problem statements, three main objectives have been set up for this study, which are:

1. To identify the sources and characteristics of the solid waste for proper documentation making.
2. To reduce the total wastes.
3. To estimate the energy content.

1.4 Project Scope

The scope of this project comprises of waste sample collection from one industrial and two residential areas; characterization of the waste sample by using quartering method with sample size of about 100kg each; and estimation of its moisture content, specific weight and energy content.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

An ever-expanding population and high rates of economic development in Malaysia resulted in the generation of huge amount of waste. According to Ministry of Housing and Local Government, it is estimated about 17,000 of waste generated in Peninsular Malaysia in 2003. As the solid waste management system handles huge quantities of solid waste, it is necessary to have detailed information on quantification and characterization of solid waste for proper handling of solid waste at different stages of the system.

2.2 Quantification of Municipal Solid Waste

Gawaikar & Deshpande (2006) observed that the most important aspect of solid waste management is the quantity of waste to be managed. The quantities are measured in terms of weight and volume. It determines the size and number of functional units, and also equipments required for managing the waste.

Tchobanoglous *et al.* (1993) said that waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data, or some combination of the two approaches. There are three methods commonly used to assess the quantities which are load count analysis, weight volume analysis, and material balance analysis.

Another method is by using materials-flow surveys based on 'production data for the materials and products in the waste stream, with adjustments for imports, exports, and product lifetimes' (USEPA, 1996). Based on production data, an estimate is made for the total weight of waste generated.

2.3 Determination of Sampling

Zeng *et al.* (2003) said that seasonal variation and geographical variation can have a significant impact on waste characteristics, thus sampling was designed to be two-way stratified which are seasonal stratification and geographical stratification. In small scope, Kharagpur municipality collects solid waste for five working days from each of four different community bins. (Kumar and Goel, 2008).

Beside that, sample weight also affects the variability of estimation. If the sample weight is too small, the result will be inaccurate as the big component in the waste like wood can not be physically included in the small sample. Klee (1980) indicated that the smaller the sample weight, the greater the variance of the waste sample composition. He stated that as sample weight decreased from approximately 91 kg, the sample variance increased rapidly, but that above approximately 140 kg, the variance increased much more slowly. He thus recommended a sample weight between 91 kg and 140 kg.

The 2002 Wisconsin study (Cascadia Consulting Group, Inc. 2003) was a state-wide waste characterization study. Samples were collected from 14 landfills during two sampling days between August and December 2002. The average sample weight for the 400 samples was about 113 kg.

2.4 Characterization of Municipal Solid Waste

In Chihuahua, the waste was characterized into six main groups which are organic, paper, plastic, metals, glass, and others. (Gomez et al, 2008). The percentage of each composition is shown in Figure 2.1.

While in Ireland, Kundell (1996) observed that waste composition of municipal solid waste consists of paper and paperboard 37.6%, yard waste 15.9%, plastic 9.3%, metals 8.3%, wood 6.6%, glass 6.6%, food waste 6.7% and miscellaneous inorganics (including textile, rubber, leather and other) 9.1%. The result is shown in Figure 2.2.

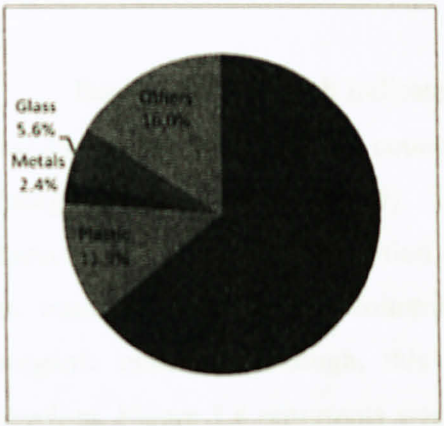

Figure 2.1: Waste characterization in Chihuahua (2006)

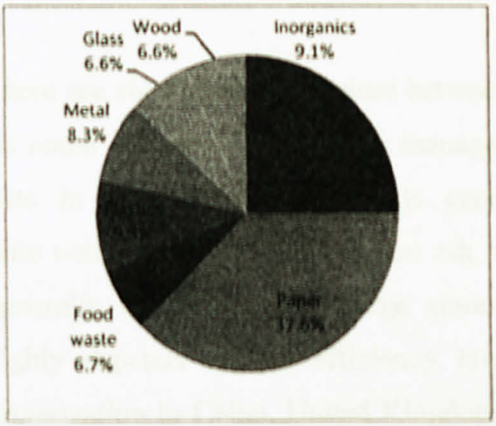

Figure 2.2: Waste characterization in Ireland (1996)

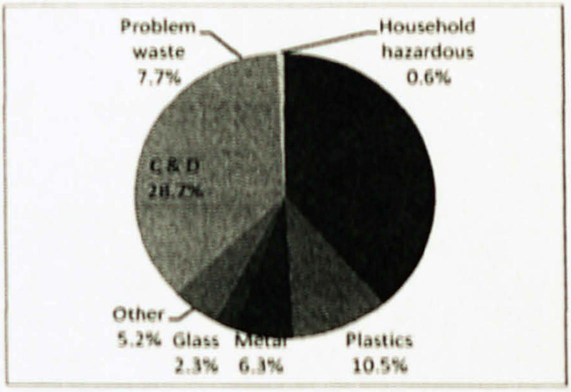

Figure 2.3: Waste characterization in Wisconsin (2002)

From 2002 Wisconsin study, the waste was classified into nine broad materials (Cascadia Consulting Group, Inc. 2003). As shown in Figure 2.3, waste from construction and demolition activities (C&D), paper, and organic materials made the biggest portion of the state's overall waste stream.

The composition of waste varies from country to another country and city to another city. For Ireland in 1996, the percentage of paper waste was greater than Wisconsin in 2002 and Chihuahua in 2006. It can be said that Ireland at that time was producing a lot of paper waste and in the same time, recycling system was not well implemented in the country. While in Wisconsin and Chihuahua, the paper waste was lesser since the recycling system was well managed compare to Ireland in 1996.

Beside that, research indicates that there are significant differences between the developing and industrialized countries that could influence solid waste management strategy (Grover *et al.*, 2000). The waste in developing countries is generally characterized by a large proportion of organic waste, moisture content, and ash, while the waste in industrialized countries is generally dominated by a large amount of inorganic materials. Though, this also highly depends on the efficiency level of recycling. Figure 2.4 represents waste characterization in China, United Kingdom, and Japan which recorded by UNEP, 1996.

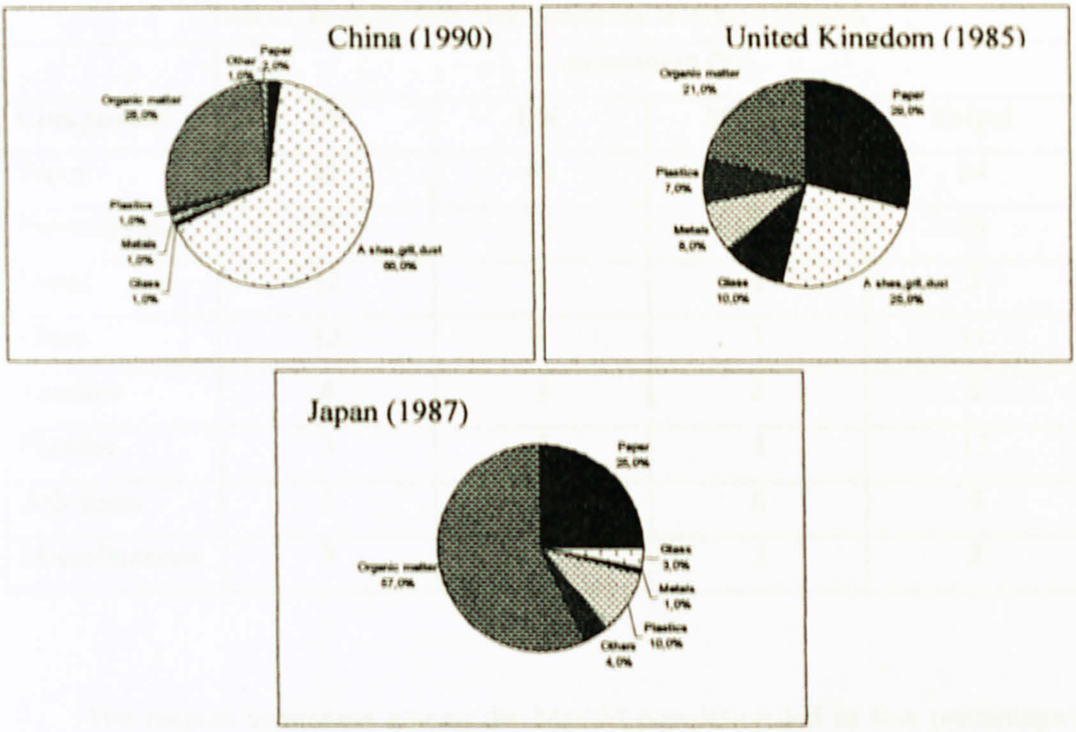

Figure 2.4: Composition of national waste flows.

In the mid 1980s, Japan seemed did not maintain a well-developed recycling system for organic waste as its organic waste was higher than two other countries. Japan in 1987 and China in 1990 were developing countries at that time. While United Kingdom was more towards industrialized country as it produced a large number of inorganic materials such as plastics, metals, and glass.

While among different industrialized countries themselves, there are also some variations that can be found (Pteffer, 1992). Table 2.1 shows the data of waste composition for four industrialized countries that had been taken in the late 1970s except for Taipei. The Taipei data were collected in 1982.

Table 2.1: Municipal Solid Waste Composition of Different Countries.

	Composition (%)			
Component	**US**	**UK**	**Madrid**	**Taipei**
Paper	33	43	18	24
Putrescibles	31	17	50	29
Metal	12	9	4	5
Glass	12	9	3	11
Textiles	4	3	2	8
Plastics	3	5	4	12
Ash-fines	2	12	6	9
Miscellaneous	3	2	3	2

The recycle awareness among the Madrid population led to low percentage of paper and glass wastes. At this time, the "throwaway" attitude was not common in Spain. Natural fibers are in short supply in Spain and much of Europe, thus paper recycle is attractive. In Taipei, there was relatively low paper content but high plastic content. In countries with less forest, the paper fibers were limited, hence plastic became cheaper than paper to be used in packaging. Beside that, reusable glass containers were used extensively for beverages. The low content of putrescible materials in UK was a result of preference for prepared food as compared to fresh food like fish and meat.

2.5 Physical and Chemical Properties of Municipal Solid Waste

Moisture content and specific weight are physical properties of municipal solid waste while ultimate analysis and energy content are chemical properties of municipal solid waste. These properties can be determined from the waste's compositions which need detailed calculation. Table 2.2 shows comparison of typical components distribution, moisture content, and ultimate analysis in municipal solid waste between

Thailand, UK, and US. The data of Thailand and UK are taken from article by Patumsawad S. and Cliffe K.R. (2002) while the data of US is taken from text book by Tchobanoglous G. (1993).

Table 2.2: The Comparison of Typical Distribution of Components, Moisture Content, and Ultimate Analysis

Component	**Thailand**	**UK**	**US**
Paper	13%	31%	34%
Food waste	39%	25%	27.5%
Textiles, rubber, leather, and wood	23%	5%	11%
Plastics	10%	8%	7%
Metal		8%	3%
Glass	15%	10%	8%
Other		13%	6.5%
Ash	13.40%	22.30%	3%
Moisture content	58.40%	32.43%	21.2%
Ultimate analyses (dry-basis)			
Combustible, wt,%	67.79	67.00	94.01
Carbon	37.14	35.81	47.14
Hydrogen	5.41	4.82	6.23
Oxygen	24.93	24.43	39.54
Nitrogen	0.22	0.78	0.93
Sulphur	0.09	0.41	0.17
Chlorine	0.80	0.75	
Ash, wt,%	32.21	33.00	5.99

Moisture content in Thailand municipal solid waste is higher than others because Thailand is developing country compared to UK and US which are developed countries. Developed or industrial countries usually have much lower moisture content. Another factor that affects the moisture content value is geographic location. Thailand which is located near equator line, receives rain over a year compared to US and UK that have four seasons.

Based on those physical composition, moisture content, and ultimate analyses data, energy content can be determined. The easiest way is by using Modified Dulong's Formula as shown below:

$$\text{Btu/lb} = 145C + 610\,(H_2 - (1/8)\,O_2) + 40S + 10N \quad \text{..................[2.1]}$$

As calculated in text book by Tchobanoglous G. (1993), the energy content in US municipal solid waste in 1990 is 5 772 Btu/lb or 13 426 kJ/kg.

2.6 Conclusion

For municipal solid waste characterization study, sample weight of about 100 kg need to be collected from several sources on different days or season. This is because source of the waste and day of collected waste affect the result of waste characteristics. With physical composition, moisture content and ultimate analysis data, energy content then can be calculated by using Modified Dulong's Formula.

CHAPTER 3
METHODOLOGY

3.1 Introduction

There were three main steps in determining the composition and quantities of the solid waste which were collecting, sorting, and analyzing.

3.2 Collecting

Three establishments were identified which were Jelapang (Chinese residential area), Taman Meru (Malay residential area), and Puncak Jelapang (industrial area). The wastes from the three different establishments were collected on Wednesday and Friday by door-to-door collection as shown in Figure 3.1, or deposited by residents in small and large community bins.

Figure 3.1: Door-to-door collection

Figure 3.2: Waste was weighed

The waste from each establishment was weighed by using electronics weighing equipment as shown in Figure 3.2, until it reached about 100 kg. Then, the 100 kg waste was brought to an open space for quartering activity. It was mixed thoroughly on the floor as shown in Figure 3.3 and flattened into square shape as shown in Figure 3.4.

Figure 3.3: Waste was mixed thoroughly

Figure 3.4: Waste was flattened into square shape

The square shape of waste was equally divided into four parts as depicted in Figure 3.5 and Figure 3.6. By using Table 27 from book of "New Cambridge Elementary Statistical Tables" as attached in appendices, one part was chosen.

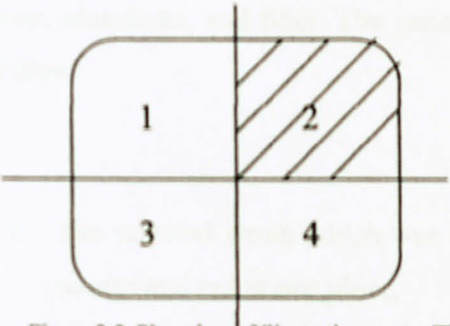

Figure 3.5: Plan view of illustration waste. The shaded area was the chosen area.

Figure 3.6: Waste was divided into four parts

From the chosen part, it was divided into another four smaller parts. Then one of the parts was chosen by using the same method as before. This chosen waste was waste sample that will be sorted.

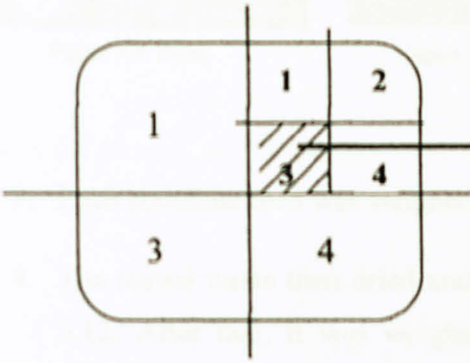

Figure 3.7: Illustration of one of the small parts that was chosen

Figure 3.8: One part that was chosen from second division of the waste

3.3 Sorting

After sampling, the waste was manually sorted into predetermined categories which were paper, plastics, plastic container, metal & rubber, glass, food waste, fabric, leather, aluminum, and fiber. The general sorting procedures of the waste samples were as follow:

1. The selected waste which was taken as a sample, was separated from the other wastes and put at one place.
2. All of the waste material within the sample were physically sorted and put into specific container according to predetermined category as shown in Figure 3.9, 3.10, and 3.11.

Figure 3.9: Paper

Figure 3.10: Food waste

Figure 3.11: Plastic

3. Each container then was weighed and recorded as 'wet weight of waste'.

4. The sorted waste then dried under the sun for several days as shown in Figure 3.12. After that, it was weighed again and recorded as 'air-dried weight of waste'.

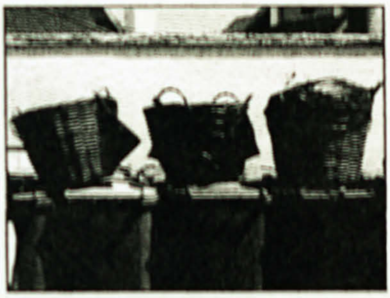

Figure 3.12: Sorted wastes are dried under the sun

During sorting, any unique characteristics of the material such as significant moisture or hazardous were noted on the data form. The data attained from the sorting provided a basis for characterizing each of the waste streams.

3.4 Analyzing

All the data recorded in the field were transferred into an Excel spreadsheet file. A spreadsheet was created for each sample collected and included the information gathered, the predetermined categories, weight measurement for each category, and the day the waste sample represented.

The percentage of each category was calculated by using the following formula:

$$\%\text{ weight of individual component} = \frac{\text{Weight of individual component}}{\text{Sum weight of all components}} \times 100 \qquad [3.1]$$

$$\%\text{ moisture content of individual component} = \frac{(\text{wet weight}) - (\text{air-dried weight})}{\text{wet weight}} \times 100 \qquad [3.2]$$

$$\text{Specific weight of individual component} = \frac{\text{Weight of individual component}}{\text{Volume as per collected}} \qquad [3.3]$$

The value of moisture content and specific weight then compared to the typical value in Table 6 that is attached in Appendix 2. This typical value is taken from text book written by Tchobanoglous G. (1993)

Based on the physical composition and moisture content data, ultimate analysis was calculated, and then finally energy content was estimated. For the calculation, the percentage distributions of the major elements composing the waste (carbon, hydrogen, oxygen, nitrogen, sulfur, and ash) were computed by referring to Table 7 in Appendix 3. The further calculation for ultimate analysis and energy content were shown in the result.

CHAPTER 4
RESULT AND DISSCUSSION

4.1 Introduction

A total of six waste samples had been taken and characterized, which half of them were taken on Wednesday and another half was taken on Friday, from three different sources. The data are recorded in details in the tables and analyzed according to the different sources.

4.2 Data Collected

Table 4.1, 4.2, and 4.3 show the weight percentages, wet weight, and dry weight for each components of the waste sample that had been collected from Jelapang residential area, Taman Meru residential area, and Puncak Jelapang industrial area.

Table 4.1: Weight of the waste components from Jelapang

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Weight %	**Wet Weight (kg)**	**Dry Weight (kg)**	**Weight %**	**Wet Weight (kg)**	**Dry Weight (kg)**
Paper	7.30	0.375	0.285	18.14	1.214	1.180
Plastic	8.75	0.450	0.430	7.39	0.495	0.493
Plastic container	1.17	0.060	0.060	0.30	0.020	0.020
Metal & Rubber	0.19	0.010	0.010	0.07	0.005	0.005
Glass	0.00	0.000	0.000	5.23	0.350	0.350
Food waste	79.28	4.075	1.920	57.14	3.825	2.195
Fabric	3.31	0.170	0.098	11.73	0.785	0.770
Leather	0.00	0.000	0.000	0.00	0.000	0.000
Aluminum	0.00	0.000	0.000	0.00	0.000	0.000
Fiber	0.00	0.000	0.000	0.00	0.000	0.000
TOTAL	**100**	**5.14**	**2.803**	**100**	**6.694**	**5.013**

Table 4.2: Weight of the waste components from Taman Meru

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Weight %	**Wet Weight (kg)**	**Dry Weight (kg)**	**Weight %**	**Wet Weight (kg)**	**Dry Weight (kg)**
Paper	11.37	0.590	0.320	20.44	0.930	0.850
Plastic	15.22	0.790	0.730	12.42	0.565	0.565
Plastic container	4.24	0.220	0.210	14.95	0.680	0.600
Metal & Rubber	0.00	0.000	0.000	7.69	0.350	0.350
Glass	0.00	0.000	0.000	0.00	0.000	0.000
Food waste	54.91	2.850	0.580	38.13	1.735	0.480
Fabric	5.20	0.270	0.180	6.04	0.275	0.250
Leather	9.06	0.470	0.400	0.00	0.000	0.000
Aluminum	0.00	0.000	0.000	0.33	0.015	0.015
Fiber	0.00	0.000	0.000	0.00	0.000	0.000
TOTAL	**100**	**5.19**	**2.42**	**100**	**4.550**	**3.11**

Table 4.3: Weight of the waste components from Puncak Jelapang

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Weight %	Wet Weight (kg)	Dry Weight (kg)	Weight %	Wet Weight (kg)	Dry Weight (kg)
Paper	16.39	0.885	0.780	10.35	0.655	0.545
Plastic	8.15	0.440	0.425	15.96	1.010	0.980
Plastic container	1.76	0.095	0.095	6.24	0.395	0.395
Metal & Rubber	3.70	0.200	0.200	1.74	0.110	0.110
Glass	11.85	0.640	0.640	23.22	1.470	1.455
Food waste	3.98	0.215	0.155	13.43	0.850	0.479
Fabric	4.81	0.260	0.255	0.00	0.000	0.000
Leather	4.81	0.260	0.260	0.00	0.000	0.000
Aluminum	0.00	0.000	0.000	16.59	1.050	1.045
Fiber	44.54	2.405	1.695	12.48	0.790	0.460
TOTAL	**100**	**5.4**	**4.505**	**100**	**6.330**	**5.469**

Food waste is the major composition generated by people in residential areas. The generation on Wednesday (15^{th} July 2009) is higher than the generation on Friday (9^{th} October 2009) because Jun to August is fruit season in Malaysia especially durian while October is the beginning of raining season. It shows that the season also affects the waste generation.

Beside that, the food waste generation in Jelapang which is Chinese residential area is higher than the one that generated in Taman Meru which is Malay residential area. This is because most of the Chinese in Jelapang are involve in agricultural business. They sell vegetables and foods at the nearby market, and bring back the unsold groceries.

While in industrial area, food waste is not the main composition. Puncak Jelapang industrial area consists of paper factories, signboard factories, steels factories and others excluding food factories. Thus, the composition of food waste is just come from workers meal, and not as high as from residential areas. The industrial waste compositions with high weight are paper, plastic, glass, aluminum, and fiber.

The highest weight of waste components produced by industrial area in Puncak Jelapang is glass, followed by aluminum, plastic, food waste, fiber, paper, plastic container, and metal & rubber. Although the percentage of glass weight is greatest, it does not mean that the industrial area produces a lot of glass. As identified, most of the factories in Puncak Jelapang industrial area are producing cardboard, signage, and paper. However, because of its light weight (e.g. paper), the huge quantities of it does not contribute much to the weight percentage compared to glass.

4.3 Physical Properties of the Solid Waste.

4.3.1 Moisture Content.

From data collected, the value of moisture content can be calculated. The detailed calculation is shown in Appendix 4. Table 4.4 below represents the comparison of moisture content based on wet weight basis for Jelapang residential area, Taman Meru residential area, and Puncak Jelapang industrial area respectively.

Table 4.4: Comparison of Moisture Content between the Waste Components from Jelapang, Taman Meru, and Puncak Jelapang

CLASSIFICATION	MOISTURE CONTENT (wet-basis), %					
	WEDNESDAY			FRIDAY		
	Jelapang	Taman Meru	Puncak Jelapang	Jelapang	Taman Meru	Puncak Jelapang
Paper	24.0	45.8	11.9	2.8	8.6	16.8
Plastic	4.4	7.6	3.4	0.4	0.0	3.0
Plastic container	0.0	4.5	0.0	0.0	11.8	0.0
Metal & Rubber	0.0	0.0	0.0	0.0	0.0	0.0
Glass	0.0	0.0	0.0	0.0	0.0	1.0
Food waste	52.9	79.6	27.9	42.6	72.3	43.6
Fabric	42.4	33.3	1.9	1.9	9.1	0.0
Leather	0.0	14.9	0.0	0.0	0.0	0.0
Aluminum	0.0	0.0	0.0	0.0	0.0	0.5
Fiber	0.0	0.0	29.5	0.0	0.0	41.8
OVERALL	45.47	53.4	16.57	25.11	31.6	13.60

By referring to Table 6 in Appendix 2, typical moisture content for textile is 10% , compared to moisture content of fabric for waste taken from Jelapang and Taman Meru on Wednesday that are 42.4% and 33.3% respectively. These values contribute to high overall moisture content of the same sample wastes that are 45.47% and 53.4%.

Table 4.5 below shows the average moisture content for Jelapang, Taman Meru, and Puncak Jelapang.

Table 4.5: Average Moisture Content in the Waste from Jelapang, Taman Meru, and Puncak Jelapang

AREA	AVERAGE MOISTURE CONTENT, %
Jelapang	35.29
Taman Meru	42.50
Puncak Jelapang	15.09

In the text book written by Tchobanoglous G. (1993), the typical moisture content calculated from total weight of all residential waste components is about 20%. However, Table 4.5 above shows that the moisture content of wastes taken from Jelapang and Taman Meru residential areas are higher. These high moisture contents are contributed by rain water as the waste samples are taken between July and October that is nearly raining season.

While for Puncak Jelapang, the moisture content is lower than 20% as it is an industrial area.

4.3.2 Specific Weight.

The value of specific weight was calculated as the volume was collected from container with no compaction. The detailed calculation of specific weight is shown in Appendix 5. Table 4.6 below represents the comparison of specific weight value for each waste component from Jelapang, Taman Meru, and Puncak Jelapang.

Table 4.6: Comparison of Specific Weight for the waste components from Jelapang, Taman Meru, and Puncak Jelapang

CLASSIFICATION	SPECIFIC WEIGHT, kg/m^3					
	WEDNESDAY			FRIDAY		
	Jelapang	Taman Meru	Puncak Jelapang	Jelapang	Taman Meru	Puncak Jelapang
Paper	58.889	74.122	55.591	65.363	50.072	38.876
Plastic	32.615	58.381	21.260	23.320	30.420	14.987
Plastic container	12.563	23.032	8.137	1.077	24.408	20.932
Metal & Rubber	18.844	0.000	25.126	47.111	25.126	10.201
Glass	0.000	0.000	120.605	75.378	0.000	94.835
Food waste	511.941	537.067	81.031	411.886	272.459	180.178
Fabric	17.798	50.880	28.821	169.062	59.225	0.000
Leather	0.000	63.264	16.332	0.000	0.000	0.000
Aluminium	0.000	0.000	0.000	0.000	4.711	41.009
Fiber	0.000	0.000	1266.329	0.000	0.000	479.317
OVERALL	119.581	105.733	59.308	86.877	48.856	39.228

Specific weight data are often needed to access the total mass and volume of waste that must be managed. Unfortunately, there is little or no uniformity in the way solid waste specific weights have been reported in the literature. Frequently, no distinction has been made between uncompacted or compacted specific weights.

As compared to Table 6 in Appendix 2, the values of specific weight are quiet different. These results are affected by size of container that had been used to estimate the volume of the waste in uncompacted condition.

4.4 Chemical Properties of the Solid Waste.

4.4.1 Ultimate Analysis.

Solid Waste from Jelapang Residential Area

By referring to Table 7 in Appendix 3, the chemical composition of the municipal solid waste was calculated. Table 4.7 shows the percentage distribution of the major elemental composition of the waste from Jelapang residential area.

Table 4.7: Percentage distribution of elements in the waste components

CLASSIFICATION	AVERAGE (wet weight, kg)	AVERAGE (dry weight, kg)	Composition, kg					
			C	H	O	N	S	Ash
Paper	0.79	0.73	0.32	0.04	0.32	0.00	0.00	0.04
Plastic	0.47	0.46	0.28	0.03	0.11	0.00	0.00	0.05
Plastic container	0.04	0.04	0.02	0.00	0.01	0.00	0.00	0.00
Metal & Rubber	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Glass	0.18	0.18	0.00	0.00	0.00	0.00	0.00	0.17
Food waste	3.95	2.06	0.99	0.13	0.77	0.05	0.01	0.10
Fabric	0.48	0.43	0.21	0.03	0.17	0.01	0.00	0.01
Leather	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aluminium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fiber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**5.92**	**3.91**	**1.82**	**0.24**	**1.39**	**0.07**	**0.01**	**0.39**

The percentage distribution of the elements without and with water contained in the waste; and molar composition of the elements are summarized in Table 4.8 as below. While Table 4.9 shows the normalized mole ratios.

Table 4.8: Percentage distribution (without and with water) and molar computation for waste elements

Component	Weight, kg		Atomic weight, kg/mole	Moles	
	Without H_2O	With H_2O		Without H_2O	With H_2O
Carbon	1.82	1.82	12.01	0.152	0.152
Hydrogen	0.24	0.46	1.01	0.237	0.459
Oxygen	1.39	3.17	16.00	0.087	0.198
Nitrogen	0.07	0.07	14.01	0.005	0.005
Sulfur	0.01	0.01	32.07	0.000	0.000
Ash	0.39	0.39	-	-	-

Table 4.9: Normalized mole ratios for each element

Component	Mole ratio (Nitrogen = 1)		Mole ratio (Sulfur = 1)	
	Without H_2O	With H_2O	Without H_2O	With H_2O
Carbon	32.5	32.5	455.1	455.1
Hydrogen	50.7	98.4	710.0	1379.4
Oxygen	18.6	42.4	260.2	594.9
Nitrogen	1.0	1.0	14.0	14.0
Sulfur	0.1	0.1	1.0	1.0

An approximate chemical formula without and with sulfur; and without and with water are determined as the following:

The chemical formulas without sulfur are:

1	Without water	$C_{32.5}\ H_{50.7}\ O_{18.6}\ N$
2	With water	$C_{32.5}\ H_{98.4}\ O_{42.4}\ N$

The chemical formulas with sulfur are:

1	Without water	$C_{455.1}\ H_{710.0}\ O_{260.2}\ N_{14.0}\ S$
2	With water	$C_{455.1}\ H_{1379.4}\ O_{594.9}\ N_{14.0}\ S$

Table 4.10 shows the percentage distribution of the major elemental composition of the waste from Taman Meru area.

Table 4.10: Percentage distribution of elements in the waste components

CLASSIFICATION	AVERAGE (wet weight, kg)	AVERAGE (dry weight, kg)	Composition, kg					
			C	H	O	N	S	Ash
Paper	0.76	0.59	0.25	0.03	0.26	0.00	0.00	0.04
Plastic	0.68	0.65	0.39	0.05	0.15	0.00	0.00	0.06
Plastic container	0.45	0.41	0.24	0.03	0.09	0.00	0.00	0.04
Metal & Rubber	0.18	0.18	0.12	0.02	0.00	0.00	0.00	0.04
Glass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food waste	2.29	0.53	0.25	0.03	0.20	0.01	0.00	0.03
Fabric	0.27	0.22	0.10	0.01	0.09	0.00	0.00	0.01
Leather	0.24	0.20	0.12	0.02	0.02	0.02	0.00	0.02
Aluminium	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Fiber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**4.87**	**2.77**	**1.49**	**0.19**	**0.81**	**0.04**	**0.01**	**0.24**

The percentage distribution of the elements without and with water contained in the waste; and molar composition of the elements are summarized in Table 4.11 as below. While Table 4.12 shows the normalized mole ratios.

Table 4.11: Percentage distribution (without and with water) and molar computation for waste elements

Component	Weight, kg		Atomic weight, kg/mole	Moles	
	Without H_2O	With H_2O		Without H_2O	With H_2O
Carbon	1.49	1.49	12.01	0.124	0.124
Hydrogen	0.19	0.42	1.01	0.187	0.420
Oxygen	0.81	2.68	16.00	0.050	0.167
Nitrogen	0.04	0.04	14.01	0.003	0.003
Sulfur	0.01	0.01	32.07	0.000	0.000
Ash	0.24	0.24	-	-	-

Table 4.12: Normalized mole ratios for each element

Component	Mole ratio (Nitrogen = 1)		Mole ratio (Sulfur = 1)	
	Without H_2O	With H_2O	Without H_2O	With H_2O
Carbon	43.0	43.0	541.8	541.8
Hydrogen	65.0	146.3	818.4	1841.9
Oxygen	17.6	58.2	221.2	733.0
Nitrogen	1.0	1.0	12.6	12.6
Sulfur	0.1	0.1	1.0	1.0

An approximate chemical formula without and with sulfur; and without and with water are determined as the following:

The chemical formulas without sulfur are:

1	Without water	$C_{43.0}H_{65.0}O_{17.6}N$
2	With water	$C_{43.0}H_{146.3}O_{58.2}N$

The chemical formulas with sulfur are:

1	Without water	$C_{541.8}H_{818.4}O_{221.2}N_{12.6}S$
2	With water	$C_{541.8}H_{1841.9}O_{733.0}N_{12.6}S$

Solid Waste from Puncak Jelapang Industrial Area

Table 4.13 shows the percentage distribution of the major elemental composition of the waste from Puncak Jelapang industrial area.

Table 4.13: Percentage distribution of elements in the waste components

CLASSIFICATION	AVERAGE (wet weight, kg)	AVERAGE (dry weight, kg)	Composition, kg					
			C	H	O	N	S	Ash
Paper	0.77	0.66	0.29	0.04	0.29	0.00	0.00	0.04
Plastic	0.73	0.70	0.42	0.05	0.16	0.00	0.00	0.07
Plastic container	0.25	0.25	0.15	0.02	0.06	0.00	0.00	0.02
Metal & Rubber	0.16	0.16	0.11	0.01	0.00	0.00	0.00	0.03
Glass	1.06	1.05	0.01	0.00	0.00	0.00	0.00	1.04
Food waste	0.53	0.32	0.15	0.02	0.12	0.01	0.00	0.02
Fabric	0.13	0.13	0.06	0.01	0.05	0.00	0.00	0.00
Leather	0.13	0.13	0.08	0.01	0.02	0.01	0.00	0.01
Aluminium	0.53	0.52	0.02	0.00	0.02	0.00	0.00	0.47
Fiber	1.60	1.08	0.01	0.00	0.00	0.00	0.00	1.07
TOTAL	**5.87**	**4.99**	**1.29**	**0.16**	**0.73**	**0.03**	**0.01**	**2.77**

The percentage distribution of the elements without and with water contained in the waste; and molar composition of the elements are summarized in Table 4.14 as below. While Table 4.15 shows the normalized mole ratios.

Table 4.14: Percentage distribution (without and with water) and molar computation for waste elements

Component	Weight, kg		Atomic weight, kg/mole	Moles	
	Without H_2O	With H_2O		Without H_2O	With H_2O
Carbon	1.29	1.29	12.01	0.107	0.107
Hydrogen	0.16	0.26	1.01	0.163	0.260
Oxygen	0.73	1.51	16.00	0.045	0.094
Nitrogen	0.03	0.03	14.01	0.002	0.002
Sulfur	0.01	0.01	32.07	0.000	0.000
Ash	2.77	2.77	-	-	-

Table 4.15: Normalized mole ratios for each element

Component	Mole ratio (Nitrogen = 1)		Mole ratio (Sulfur = 1)	
	Without H_2O	With H_2O	Without H_2O	With H_2O
Carbon	52.4	52.4	588.8	588.8
Hydrogen	79.4	127.0	891.8	1426.1
Oxygen	22.2	46.0	248.7	515.9
Nitrogen	1.0	1.0	11.2	11.2
Sulfur	0.1	0.1	1.0	1.0

An approximate chemical formula without and with sulfur; and without and with water are determined as the following:

The chemical formulas without sulfur are:

1 Without water $C_{52.4}H_{79.4}O_{22.2}N$
2 With water $C_{52.4}H_{127.0}O_{46.0}N$

The chemical formulas with sulfur are:

1 Without water $C_{588.8}H_{891.8}O_{248.7}N_{11.2}S$
2 With water $C_{588.8}H_{1426.1}O_{515.9}N_{11.2}S$

4.4.2 Energy Content.

Solid Waste from Jelapang Residential Area

The value of energy content was estimated based on chemical composition including sulfur and water that had been determined in ultimate analysis. Table 4.16 shows percentage distribution by weight of the elements composing the waste, using coefficient that had been rounded off.

The chemical composition of the waste including sulfur and water is:

$$C_{455.1}\ H_{1379.4}\ O_{594.9}\ N_{14.0}\ S$$

Table 4.16: Percentage distribution by weight of the elements in the waste with water.

Component	**Number of atoms per mole**	**Atomic weight**	**Weight contribution of each element**	**%**
Carbon	455	12	5462	32.93
Hydrogen	1379	1	1379	8.32
Oxygen	595	16	9518	57.38
Nitrogen	14	14	196	1.18
Sulfur	1	32	32	0.19
TOTAL			16587	100.00

The energy content of the waste by using modified Dulong formula:

$$\text{Btu/lb} = 145C + 610\,(H_2 - (1/8)\,O_2) + 40S + 10N$$
$$= 5\,491$$

kJ/kg = 12 773 as Btu/lb x 2.326 = kJ/kg

Table 4.17 shows percentage distribution by weight of the elemental composition of the waste, using coefficient that had been rounded off.

The chemical composition of the waste including sulfur and water is:

$$C_{541.8}\ H_{1841.9}\ O_{733.0}\ N_{12.6}\ S$$

Table 4.17: Percentage distribution by weight of the elements in the wet waste.

Component	**Number of atoms per mole**	**Atomic weight**	**Weight contribution of each element**	**%**
Carbon	542	12	6502	32.06
Hydrogen	1842	1	1842	9.08
Oxygen	733	16	11728	57.83
Nitrogen	13	14	176	0.87
Sulfur	1	32	32	0.16
TOTAL			20280	100.00

The energy content of the waste according to modified Dulong formula is:

$$\text{Btu/lb} = 145C + 610\,(H_2 - (1/8)\,O_2) + 40S + 10N$$
$$= 5\,794$$

$\text{kJ/kg} = 13\,478$ as $\text{Btu/lb} \times 2.326 = \text{kJ/kg}$

Solid Waste from Puncak Jelapang Industrial Area

Table 4.18 shows percentage distribution by weight of the elemental composition of the waste, using coefficient that had been rounded off.

The chemical composition of the waste including sulfur and water is:

$$C_{588.8}\ H_{1426.1}\ O_{515.9}\ N_{11.2}\ S$$

Table 4.18: Percentage distribution by weight of the elements in the wet waste.

Component	Number of atoms per mole	Atomic weight	Weight contribution of each element	%
Carbon	589	12	7066	41.72
Hydrogen	1426	1	1426	8.42
Oxygen	516	16	8255	48.74
Nitrogen	11	14	157	0.93
Sulfur	1	32	32	0.19
TOTAL			16936	100.00

The energy content of the waste according to modified Dulong formula is:

$$\text{Btu/lb} = 145C + 610\,(H_2 - (1/8)\,O_2) + 40S + 10N$$
$$= 7\,486$$

$\text{kJ/kg} = 17\,413$ as Btu/lb x 2.326 = kJ/kg

The energy content in wastes taken from Jelapang, Taman Meru, and Puncak Jelapang are summarized in Table 4.19 as below.

Table 4.19: Comparison of Energy Content in Waste from Jelapang, Taman Meru, and Puncak Jelapang

AREA	ENERGY CONTENT, kJ/kg
Jelapang	12 773
Taman Meru	13 478
Puncak Jelapang	17 413

To determine the net energy content produced by the waste, the value of energy required to increase the current temperature to 100°C and energy required to vaporize the water moisture at 100°C need to be deducted from the values of energy content in Table 4.19 above.

1.00 calories of heat is necessary to raise one gram of water to one degree Celcius. It is assumed that current temperature at the areas is about 28°C, thus the increment is about 72°C for the temperature to reach 100°C. Table 4.20 below shows the energy needed to increase the temperature of water moisture in 1 kg waste to the 100°C.

Table 4.20: Energy Required to Increase the Temperature to 100°C

AREA	MOISTURE CONTENT, g	TEMPERATURE INCREMENT, °C	ENERGY REQUIRED, Cal	ENERGY REQUIRED, kJ
Jelapang	352.9	72	25 408.8	106.36
Taman Meru	425.0	72	30 600	128.09
Puncak Jelapang	150.9	72	10 864.8	45.48

On the other hand, the amount of energy required to convert 1 kg (or 1 lb) of a substance from liquid to gas (or vice-versa) without a change in temperature is known as the specific latent heat of vaporization for that substance. Specific latent heat of vaporization for water is 2 260 kJ/kg. Table 4.21 shows the energy required to vaporize the water in 1 kg waste.

Table 4.21: Energy Required to Vaporizing the Water

AREA	MOISTURE CONTENT, g	LATENT HEAT OF VAPORIZATION, kJ/kg	ENERGY REQUIRED, kJ
Jelapang	352.9	2 260	797.6
Taman Meru	425.0	2 260	960.5
Puncak Jelapang	150.9	2 260	341.03

Finally, the net energy produced by 1 kg waste was calculated and shown in Table 4.22

Table 4.22: Net Energy Content in 1 kg Waste

AREA	ENERGY CONTENT, kJ/kg	ENERGY USED, kJ/kg	NET ENERGY PRODUCED, kJ
Jelapang	12 773	903.96	11 869
Taman Meru	13 478	1 088.59	12 389
Puncak Jelapang	17 413	386.51	17 026

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, the three objectives of the study had been achieved and can be concluded as below:

1. The data for the municipal solid waste characterization study was properly compiled and documented.
2. Total wastes on landfill site can be reduced by hardly promoting recycling and producing organic fertilizer from organic waste.
3. The estimation of energy content can help in deciding the implementation of technology to produce energy from the methane gas emission.

5.2 Recommendation

From the activities that have been handled up till now, following are some recommendations that need to be highlighted:

1. For the day of sample collections, it is recommended to collect the sample on Monday, Wednesday and Friday instead of only on Wednesday and Friday. It is because the composition of waste on Monday is quiet different than the other days as the wastes are gathered since Sunday before they are collected by waste disposal truck. Thus, the result will be more accurate if the sampling is done through out the week.

2. For calculation of moisture content, it is recommended to use oven with temperature of 105°C to dry the waste instead of drying the waste under the sun.

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APPENDICES

1. Appendix 1: TABLE 27: Random sampling numbers

2. Appendix 2: TABLE 6: Typical specific weight and moisture content data for residential, commercial, and industrial wastes.

3. Appendix 3: TABLE 7: Typical data on the ultimate analysis of the combustible materials found in residential, commercial, and industrial solid wastes.

4. Appendix 4: Detailed calculation of moisture content

5. Appendix 5: Detailed calculation of specific weight

TABLE 27. RANDOM SAMPLING NUMBERS

Each digit is an independent sample from a population in which the digits 0 to 9 are equally likely, that is, each has a probability of $\frac{1}{10}$.

84	42	56	53	87	75	18	91	76	66	64	83	97	11	69	41	80	92	38	75
28	87	77	03	57	09	85	86	46	86	40	15	31	81	78	91	30	22	88	58
64	12	39	65	37	93	76	46	11	09	56	28	94	54	10	14	30	73	80	30
49	41	73	76	49	64	06	70	99	37	72	60	39	16	02	26	91	90	16	54
06	46	69	31	24	33	52	67	85	07	01	33	16	33	43	98	17	62	52	52
75	56	96	97	65	20	68	68	60	97	90	46	63	37	10	34	41	64	85	01
09	35	89	97	97	10	00	76	39	82	49	94	15	89	60	65	57	03	91	68
73	81	11	08	52	73	64	85	22	72	85	16	15	97	76	28	41	95	00	33
49	69	80	41	46	62	26	32	58	16	88	76	54	32	06	37	46	45	28	95
64	60	49	70	33	73	71	57	83	26	19	25	86	21	64	60	11	01	86	70
93	05	36	44	59	19	99	51	54	21	37	48	18	60	22	92	68	34	39	02
39	88	11	26	68	92	81	14	12	16	37	64	61	48	21	69	77	76	33	00
89	34	19	12	83	76	35	11	96	53	04	76	63	10	93	68	52	42	73	20
77	29	03	26	45	36	15	17	27	28	79	58	38	98	73	52	63	72	48	41
86	75	51	29	70	78	24	78	94	78	64	17	32	23	95	52	87	79	14	30
95	98	77	51	14	65	76	49	42	36	11	33	23	89	32	01	60	48	91	44
22	09	01	14	04	96	97	56	92	52	83	44	45	08	72	78	10	36	26	70
30	49	36	23	36	81	11	76	91	08	67	60	01	15	64	77	21	33	72	29
77	59	88	92	17	75	04	47	18	02	94	84	71	44	87	63	06	04	49	33
03	50	80	26	74	74	18	85	92	20	64	39	98	68	29	26	90	14	77	36
46	32	79	69	41	06	26	04	47	24	67	10	66	69	21	55	66	63	48	47
65	73	98	08	05	96	92	27	22	86	54	87	95	87	40	27	09	97	47	21
68	82	77	73	08	37	28	47	73	49	10	65	53	48	87	74	02	99	52	86
93	98	12	19	82	69	61	08	00	42	88	83	70	85	08	48	74	94	88	61
61	27	39	16	42	17	89	81	27	44	12	33	43	24	92	41	55	13	45	01
54	74	04	79	72	61	21	87	23	83	96	56	97	63	67	02	67	30	36	89
28	00	40	86	92	97	06	22	37	37	83	00	97	17	08	06	43	95	76	84
61	78	71	16	41	01	69	63	35	96	60	65	09	44	93	42	72	11	22	85
68	60	92	99	60	97	53	55	34	61	43	40	77	96	19	87	63	49	22	47
21	76	13	39	25	89	91	38	25	19	44	33	11	36	72	21	40	90	76	95
73	59	53	04	35	13	12	31	88	70	05	40	43	42	47	17	03	86	14	10
85	68	66	48	05	24	28	97	84	84	91	65	62	83	89	68	07	51	01	02
60	30	10	46	44	34	19	56	00	83	20	53	53	05	29	03	47	55	23	26
44	63	80	62	80	80	99	43	33	87	70	52	51	62	02	12	02	90	44	44
89	38	13	68	31	31	97	15	35	67	23	74	76	96	62	82	62	19	65	58
55	20	77	12	79	81	42	15	30	67	88	83	69	08	99	82	20	39	92	40
67	40	42	16	46	06	60	74	61	22	95	47	24	62	81	06	19	67	15	06
57	19	76	98	65	64	55	28	34	03	58	62	35	22	67	40	04	88	17	59
21	72	97	04	82	62	09	54	35	17	22	73	35	72	53	65	95	48	55	12
46	89	95	61	31	77	14	14	24	14	91	58	76	56	19	33	98	67	09	04
99	73	85	64	96	58	61	65	60	83	62	10	87	00	82	63	39	90	83	17
85	52	98	27	40	33	09	59	80	17	22	06	84	03	41	48	76	07	26	69
50	12	17	86	50	57	91	28	42	29	83	87	00	87	93	52	53	47	08	65
92	84	02	93	44	36	93	19	08	54	76	62	31	65	94	68	38	04	62	31
69	74	30	25	68	65	19	77	57	05	71	56	91	30	16	66	70	48	78	65
51	69	76	00	20	92	58	21	24	33	74	08	66	90	61	89	56	83	39	58
27	25	81	29	75	02	85	09	58	89	77	83	03	40	21	14	45	90	54	01
44	03	62	96	68	65	24	57	44	43	07	72	59	16	04	94	23	36	55	85
40	59	49	20	48	63	35	74	33	12	96	25	59	35	07	45	80	97	19	90
92	91	07	14	82	22	50	70	75	15	69	71	31	20	60	06	99	56	57	74

Table 6: Typical specific weight and moisture content data for residential, commercial, and industrial wastes

Type of waste	Specific weight, (kg/m³)			Moisture content, % by weight		
	Range		Typical	Range		Typical
Residential (uncompacted)						
Paper	41.533	130.532	88.999	4	10	6
Plastics	41.533	130.532	65.266	1	4	2
Rubber	100.866	201.732	130.532	1	4	2
Other metals	130.532	1151.058	320.398	2	4	3
Glass	160.199	480.596	195.799	1	4	2
Food waste (mixed)	130.532	480.596	290.731	50	80	70
Textile	41.533	100.866	65.266	6	15	10
Leather	100.866	261.065	160.199	8	12	10
Aluminum	65.266	240.298	160.199	2	4	2
Commercial						
Food wastes (wet)	474.663	949.326	539.929	50	80	70
Appliance	148.332	201.732	180.965	0	2	1
Rubbish (combustible)	50.433	180.965	118.666	10	30	15
Rubbish (noncombustible)	180.965	361.931	299.631	5	15	10
Rubbish (mixed)	139.432	180.965	160.199	10	25	15
Industrial						
Metal scrap (mixed)	700.128	1501.122	898.893	0	5	-

Table 7: Typical data on the ultimate analysis of the combustible materials found in residential, commercial, and industrial solid wastes

Type of waste	Percent by weight (dry basis)					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Paper (mixed)	43.4	5.8	44.3	0.3	0.2	6.0
Plastics (mixed)	60.0	7.2	22.8	-	-	10.0
Rubber	69.7	8.7	-	-	1.6	20.0
Metals (mixed)	4.5	0.6	4.3	<0.1	-	90.5
Glass and mineral	0.5	0.1	0.4	<0.1	-	98.9
Food waste (mixed)	48.0	6.4	37.6	2.6	0.4	5.0
Textile	48.0	6.4	40.0	2.2	0.2	3.2
Leather	60.0	8.0	11.6	10.0	0.4	10.0

Detailed Calculation of Moisture Content

Table 8.1: Moisture content of the waste components from Jelapang

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)
Paper	7.30	5.54	24.0	18.14	17.63	2.8
Plastic	8.75	8.37	4.4	7.39	7.36	0.4
Plastic container	1.17	1.17	0.0	0.30	0.30	0.0
Metal & Rubber	0.19	0.19	0.0	0.07	0.07	0.0
Glass	0.00	0.00	0.0	5.23	5.23	0.0
Food waste	79.28	37.35	52.9	57.14	32.79	42.6
Fabric	3.31	1.91	42.4	11.73	11.50	1.9
Leather	0.00	0.00	0.0	0.00	0.00	0.0
Aluminum	0.00	0.00	0.0	0.00	0.00	0.0
Fiber	0.00	0.00	0.0	0.00	0.00	0.0
TOTAL	100.00	54.53	45.467	100.00	74.89	25.112

Average of moisture content = (45.47+25.11) / 2 = 35.29%

Table 8.2: Moisture content of the waste components from Taman Meru

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)
Paper	11.37	6.17	45.8	20.44	18.68	8.6
Plastic	15.22	14.07	7.6	12.42	12.42	0.0
Plastic container	4.24	4.05	4.5	14.95	13.19	11.8
Metal & Rubber	0.00	0.00	0.0	7.69	7.69	0.0
Glass	0.00	0.00	0.0	0.00	0.00	0.0
Food waste	54.91	11.18	79.6	38.13	10.55	72.3
Fabric	5.20	3.47	33.3	6.04	5.49	9.1
Leather	9.06	7.71	14.9	0.00	0.00	0.0
Aluminium	0.00	0.00	0.0	0.33	0.33	0.0
Fiber	0.00	0.00	0.0	0.00	0.00	0.0
TOTAL	100.00	46.63	53.4	100.00	68.35	31.6

Average of moisture content = (53.4+31.6) / 2 = 42.5%

Table 8.3: Moisture content of the waste components from Puncak Jelapang

CLASSIFICATION	WEDNESDAY			FRIDAY		
	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)	Wet Weight (%)	Dry Weight (%)	Moisture Content (%)
Paper	16.39	14.44	11.9	10.35	8.61	16.8
Plastic	8.15	7.87	3.4	15.96	15.48	3.0
Plastic container	1.76	1.76	0.0	6.24	6.24	0.0
Metal & Rubber	3.70	3.70	0.0	1.74	1.74	0.0
Glass	11.85	11.85	0.0	23.22	22.99	1.0
Food waste	3.98	2.87	27.9	13.43	7.57	43.6
Fabric	4.81	4.72	1.9	0.00	0.00	0.0
Leather	4.81	4.81	0.0	0.00	0.00	0.0
Aluminium	0.00	0.00	0.0	16.59	16.51	0.5
Fiber	44.54	31.39	29.5	12.48	7.27	41.8
TOTAL	100.00	83.43	16.57	100.00	86.40	13.60

Average of moisture content = (16.57+13.60) / 2 = 15.09%

Table 9.1: Specific weight of the waste components from Jelapang

CLASSIFICATION	WEDNESDAY					FRIDAY				
	Thickness (m)	**Diameter (m)**	**Volume as collected (m3)**	**Wet Weight (kg)**	**Specific weight (kg/m3)**	**Thickness (m)**	**Diameter (m)**	**Volume as collected (m3)**	**Wet Weight (kg)**	**Specific weight (kg/m3)**
Paper	0.12	0.26	0.0064	0.375	58.889	0.35	0.26	0.0186	1.214	65.363
Plastic	0.26	0.26	0.0138	0.450	32.615	0.40	0.26	0.0212	0.495	23.320
Plastic container	0.09	0.26	0.0048	0.060	12.563	0.35	0.26	0.0186	0.020	1.077
Metal & Rubber	0.01	0.26	0.0005	0.010	18.844	0.00	0.26	0.0001	0.005	47.111
Glass	0.00	0.00	0.0000	0.000	0.000	0.09	0.26	0.0046	0.350	75.378
Food waste	0.15	0.26	0.0080	4.075	511.941	0.18	0.26	0.0093	3.825	411.886
Fabric	0.18	0.26	0.0096	0.170	17.798	0.09	0.26	0.0046	0.785	169.062
Leather	0.00	0.00	0.0000	0.000	0.000	0.00	0.00	0.0000	0.000	0.000
Aluminium	0.00	0.00	0.0000	0.000	0.000	0.00	0.00	0.0000	0.000	0.000
Fiber	0.00	0.00	0.0000	0.000	0.000	0.00	0.00	0.0000	0.000	0.000
TOTAL			0.0430	5.14	119.581			0.0771	6.694	86.877

Table 9.2: Specific weight of the waste components from Taman Meru

CLASSIFICATION	Thickness (m)	Diameter (m)	Volume as collected (m3)	Wet Weight (kg)	Specific weight (kg/m3)	Thickness (m)	Diameter (m)	Volume as collected (m3)	Wet Weight (kg)	Specific weight (kg/m3)
Paper	0.15	0.26	0.0080	0.590	74.122	0.35	0.26	0.0186	0.930	50.072
Plastic	0.26	0.26	0.0135	0.790	58.381	0.35	0.26	0.0186	0.565	30.420
Plastic container	0.18	0.26	0.0096	0.220	23.032	0.53	0.26	0.0279	0.680	24.408
Metal & Rubber	0.00	0.00	0.0000	0.000	0.000	0.26	0.26	0.0139	0.350	25.126
Glass	0.00	0.00	0.0000	0.000	0.000	0.00	0.00	0.0000	0.000	0.000
Food waste	0.10	0.26	0.0053	2.850	537.067	0.12	0.26	0.0064	1.735	272.459
Fabric	0.10	0.26	0.0053	0.270	50.880	0.09	0.26	0.0046	0.275	59.225
Leather	0.14	0.26	0.0074	0.470	63.264	0.00	0.00	0.0000	0.000	0.000
Aluminium	0.00	0.00	0.0000	0.000	0.000	0.06	0.26	0.0032	0.015	4.711
Fiber	0.00	0.00	0.0000	0.000	0.000	0.00	0.00	0.0000	0.000	0.000
TOTAL			0.0491	5.19	105.733			0.0931	4.550	48.856

Table 9.3: Specific weight of the waste components from Puncak Jelapang

CLASSIFICATION	Thickness (m)	Diameter (m)	Volume as collected (m3)	Wet Weight (kg)	Specific weight (kg/m3)	Thickness (m)	Diameter (m)	Volume as collected (m3)	Wet Weight (kg)	Specific weight (kg/m3)
Paper	0.30	0.26	0.0159	0.885	55.591	0.32	0.26	0.0168	0.655	38.876
Plastic	0.39	0.26	0.0207	0.440	21.260	1.27	0.26	0.0674	1.010	14.987
Plastic container	0.22	0.26	0.0117	0.095	8.137	0.36	0.26	0.0189	0.395	20.932
Metal & Rubber	0.15	0.26	0.0080	0.200	25.126	0.20	0.26	0.0108	0.110	10.201
Glass	0.10	0.26	0.0053	0.640	120.605	0.29	0.26	0.0155	1.470	94.835
Food waste	0.05	0.26	0.0027	0.215	81.031	0.09	0.26	0.0047	0.850	180.178
Fabric	0.17	0.26	0.0090	0.260	28.821	0.00	0.00	0.0000	0.000	0.000
Leather	0.30	0.26	0.0159	0.260	16.332	0.00	0.00	0.0000	0.000	0.000
Aluminium	0.00	0.00	0.0000	0.000	0.000	0.48	0.26	0.0256	1.050	41.009
Fiber	0.60	0.06	0.0019	2.405	1266.329	0.52	0.06	0.0016	0.790	479.317
TOTAL			0.0911	5.4	59.308			0.1614	6.330	39.228